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GEOLOGY *of the* OIL SHALES *of the* EASTERN UNITED STATES

By

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Director and State Geologist

KENTUCKY GEOLOGICAL SURVEY
FRANKFORT, KENTUCKY
1927

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Geology of the Oil Shales of the Eastern United States

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THE CHATTANOOGA (DEVONIAN) SHALE

These sediments are intensely black when fresh and break with a conchoidal fracture as indicated in the face of this recent exposure. This view was taken near Clay City, Kentucky.

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Presented by the Writer before
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Illustrated with eight photographs and one map

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*Geology of the Oil Shales of the Eastern United States**

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INTRODUCTION

Much interest has been evidenced during the past decade by European economic geologists in the petroleum reserves of the United States. As the field of productive exploration has migrated southwestward from the States of New York and Pennsylvania through West Virginia, Ohio and Kentucky to Oklahoma, Louisiana, Texas and California, speculation has been rife as to the probable source and volume of the future domestic supply of oil in the great North American republic. Even the large recent finds of Southern California and Arkansas, coupled with the excellent settled production of such well defined fields as those of Illinois, Indiana and Kansas have failed to shake the pessmistic contentions of many well informed men. It is indicated that at the present rate of about 714,000,000 barrels per annum—70 per cent of the world's annual production—the petroleum resources of the United States must soon face appreciable and permanent decline. Statistics indicate that up to January 1, 1926, the United States had produced slightly in excess of 7,900,000,000 barrels of crude oil from wells. This great volume is equivalent to about 63 per cent of all the petroleum produced in the world since the Roumanian fields were opened in 1857. It has been estimated that the known undrilled proven oil reserve of the United States contains about five and one half million thousand barrels which will last at the present rate of consumption for about eight years. Continued prospecting in an area of about one million acres in which petroleum in commercial quantity is possible may extend this volume of production to fifteen or twenty years or more. Though

* Presented before the 14th International Geological Congress by the writer, May 26, 1926, at Madrid, Spain.

OUTCROP OF DEVONIAN BLACK SHALES

This map attempts to show the areal extent of the Chattanooga and New Albany shales and their correlatives in the Northern States.

a recent report[1] on American petroleum reserves depreciates the imminency of a petroleum shortage in the United States, a perusal of the statement indicates that it savors more strongly of good pleading than of good proof.

Whether the apex of petroleum production in the United States is now close at hand or still somewhere in the more distant future time alone can tell. Decline of natural petroleum production, however, is a certainty and in anticipation of this, a number of special investigations of possible substitute sources broad in scope have been carried forward during the last decade. Chief among them has been the field and laboratory examination of the bituminous shales of the United States. This work has been undertaken and advanced with such interest and enthusiasm that a very considerable body of published scientific data descriptive, analytical and statistical is now at hand in advance of any actual commercially profitable production.

Stratigraphic Units

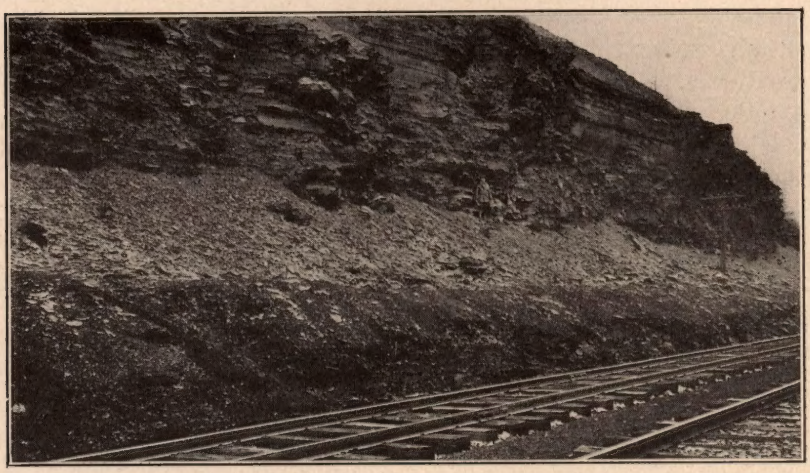
Although oil shales are broadly distributed throughout the United States, particularly in the West where great thickness and richness of Eocene deposits are encountered, it is proposed to confine this paper to a discussion of the geology and some apparent economic phases of the oil shales of the Eastern United States. A number of very adequate papers and reports[2] are available on the oil shales of Western America, some of which carry the subject into great detail. The oil shales of the Eastern United States are easily divisible into three separate units or groups on a basis of their geologic age. In ascending stratigraphic sequence they are early Upper Devonian, Lower Mississippian and Lower Pennsylvanian.

The oldest and most extensive oil shale in this Eastern region is the Upper Devonion black shale of Southern Indiana and Ohio, Central Kentucky and Tennessee, and Northern Alabama. Very secondary on any basis of consideration are several lenticular bituminous shales and cannel-shales of Pennsylvanian age stretching irregularly throughout the western Appalachian

[1] American Petroleum Supply and Demand, McGraw Hill, New York, 1925.

[2] Oil Shale of the Rocky Mountain Region, D. E. Winchester. U. S. Geol. Survey Bull. 729. 1923.

Mountain and Cumberland Plateau areas. In the mid-Appalachian district and eastward they have been so altered by regional metamorphism in the course of mountain making crustal movements as to be quite unfit for the purposes of oil and gas recovery by retorting methods. Though existing in great



DEVONIAN SHALE BULLITT COUNTY, KENTUCKY

volume in the aggregate and generally somewhat richer than the Devonian shale, the characteristic thinness of these Pennsylvanian beds of oil or cannel-shale (one to four feet generally and occasionally as much as 10 or 15 feet) renders doubtful their successful commercialization possibly for some time to come. These beds under fair conditions are capable of producing from 3 to 55 gallons of raw oil or tar to the ton,[3] best laboratory retorting methods being used.

Occuring somewhat lower in the geological column, the Sunbury shale (Waverly-Mississippian) is a thinly laminated black bituminous bed ranging about 15 to 22 feet in thickness. It is the lowest and most distinctive of the Carboniferous oil shales. This unique bed is found only east of the Cincinnati Arch where the Carboniferous formations outcrop along the western edge of the Cumberland Plateau, in Northeastern Kentucky and Southeastern Ohio. Its areal extent as com-

[3] Oil Resources in Coals and Carbonaceous Shales of Pennsylvania, Fettke, Charles R., Pennsylvania Geol. Survey, Series IV, pp. 88-91. 1923.

pared to either the Pennsylvanian or Devonian oil shales is therefore quite limited. It has produced as the result of a number of tests a maximum of 21 per cent bituminous matter.[4] An old oil shale operation near Vanceburg, Kentucky, retorted this shale for paraffin but was abandoned many years ago.

TOPOGRAPHY OF DEVONIAN OUTCROP

The view is near Panola in Madison County, Kentucy. Conical hills of oil shale capped by basal Mississippian sediments are typical.

The early Upper Devonian black shale is variously known as the Ohio, Chattanooga and New Albany shale depending upon its location and has been correlated with the Genesee shale of New York. Its outcrop runs southward from Cleveland and Sandusky across central Ohio, crosses the Ohio River near Vanceburg, and circling westward through Danville swings back to the northwest, crossing the Ohio River again at Louisville and New Albany, from which point it extends through the heart of Indiana to Lake Michigan. In Southern Kentucky it is exposed in the Cumberland River Valley and follows the highland rim of the Nashville basin of Central Kentucky with a thickness of about 30-50 feet. It reaches southward to the vicinity of Northern Alabama along the tributaries of the Middle Tennessee River and the headwaters of the Warrior River.

An extended and very irregular outcrop of this oil shale greatly thickened is found along Waldens ridge in Eastern Tennessee, Northwestern Georgia and Northeastern Alabama. This presistent bituminous formation is again found on outcrop throughout the entire Sequatchie valley, a canoe shaped anticline paralleling Waldens ridge on the west and again in

[4] Geology of Kentucky. A. M. Miller. Ky. Geol. Survey. Bull. II, p. 98. 1919.

West Central Tennessee on the west flowing tributaries of the Tennessee River to the Kentucky line. In northeastern Tennessee the Chatanooga and adjacent Devonian shales ranging from 500 to 800 feet thick follow the divide between the Clinch and Holston Rivers northeastward into southwestern Virginia,

DEVONIAN SHALE IN TENNESSEE

This view of the Chattanooga black shale is found at Baker's Station on the Louisville and Nashville Railroad in northern Davidson County, Tenn. It is exposed in this vicinity over a broad area. Photo by L. C. Coleman.

where it becomes the lower part of the thick Kimberling shale (2000-2800 feet). This group of shales in the vicinity of Staunton, is known as the Jennings formation and has thickened to about 3400 feet. Remarkable for its continuity, this formation extends northeastward through West Virginia into Eastern Pennsylvania and Southern New York where it reaches its maximum expression in thickness though in fact it is simply a unit in a long sequence of dark to black fissile carbonaceous shales extending stratigraphically from the middle Upper Devonian (Chautauquan) down to the lower Middle Devonian (Marcellus). In passing to the North, however, this formation at some undetermined point ceases to be in any commercial sense an important bituminous unit. Probably at no place after leaving Eastern Tennessee where 7 to 9 gallons of oil per ton[5] has been

[5] Oil Resources of Black Shales of the Eastern United States. George H. Ashley, U. S. Geol. Survey. Bull. 641, p. 319. 1917.

determined, is more than a very small portion of the great thickness of this formation sufficiently bituminous to be regarded as an oil shale.

Dark upper Devonian shales are found extending to the west and northwest from the type oil shale area of Southern

OIL SHALE, POWELL COUNTY, KENTUCKY

Indiana and Ohio, Central Kentucky and Tennessee, and Northern Alabama. In Missouri these dark shales are found associated with some light colored shales in the central and eastern part of the State, along the lower waters of the Missouri River, and also along the Mississippi River. Adjacent to this major waterway the dark Upper Devonian shales are quite as extensive on the Illinois side, being found in the southern part of this State as far south as Pope and Hardin Counties adjoining Kentucky. Proceeding up the Mississippi River valley to the north, upper Devonian shales dark in color yet constantly associated with lighter beds are found in Illinois near Rock Island and thence northwestward over a considerable belt of outcrop stretching through Iowa City, Cedar Rapids and Mason City to the Minnesota State line. Extending northwestward from the notable New York deposits, early Upper and late Middle Devonian shales stretch across the London peninsula of Southwestern Ontario, Canada, into the northern tip of the Michigan peninsula where in the vicinity of Alpena, Michigan,

WEATHERED EXPOSURE CHATTANOOGA SHALE

Although jet black and blocky when newly opened, old surfaces of the Devonian shale as shown above weather to a brown, and form talus of paper thinness.

these argillaceous sediments are recognized to have again increased greatly in thickness and approach probably their maximum columnar expression in the Central part of North America.

Structural Geology

The black shales of the early Upper Devonian were deposited in the Eastern United States at a time when relatively shallow waters were prevailing over a rather broad area in the northern and southern central interior regions. Broad Arctic and Pacific connections to the northwest and west respectively have been established[6] and a restricted inlet from the Atlantic across New Jersey has also been affirmed. It is probable that southern connections with the Gulf were also made through Western Alabama and Eastern Mississippi. The gradual rising of the main axis of the Cincinnati arch is noted, these black shales thinning down very perceptibly as they pass over the top of this large regional uplift in the central interior of the Eastern United States. In some places as in Central and Western Tennessee and possibly Central Northern Kentucky insular areas appeared. In these localities the black shale is absent, and the lower Mississippian shales rest disconformably on the late Lower Devonian limestones.†

As evidence of broad low angle crustal movements during the late Middle Devonian and early Upper Devonian of the central interior of the Eastern United States a comparison of some thicknesses of the Onondaga-Hamilton-Genesee sediments are illuminating. In the Blue Grass region of northern central Kentucky and central Tennessee the calcareous formations of the Onondaga and Hamilton are entirely absent. These areas are identical with the highest points of the Lexington and Nashville domes of the Cincinnati Arch. These domes were evidently islands at this time. Hamilton and Onondaga limestones of slight thickness 10-15 feet, come in rather quickly on either side and increase to a total maximum of about fifty-five feet within short distances. The maximum thickness of the Onondaga limestone series alone at northern points considerably removed from this Kentucky and Tennessee area is about 200 or 250 feet.

[6] Paleography of North America. Chas. Schuchert. Bull. of Geol. Soc. of N. Amer., Vol. 20, pp. 427-606, pls. 46-101. Feb. 1910.

†Unique Devonic Sandbar. W. R. Jillson. Pan-American Geologist, Vol. XL, pp. 333-337. Dec. 1923.

Superimposed upon the Onondaga, the Hamilton group of sediments come in principally as coral limestones in Kentucky and Tennessee. In New York and elsewhere in the north this formation exhibits thick shale and sand components reaching a maximum thickness of about 2000 or 2500 feet. These calcareous and clastic sediments were not deposited on the top of the Cincinnati Arch which continued to exhibit twin islands throughout late Middle Devonian time.

Depression of slight extent occurred in the early part of the Upper Devonian and the black Chattanooga-New Albany-Genesee shale spread almost entirely over the central interior of the Eastern United States. Well upon the sides of the Lexington and Nashville domes of the Cincinnati Arch it is thinnest, and frequently no more than 20 or 30 feet are present. Some central points indicate that it may have been removed by erosion. In others it may never have been deposited. On the Eastern and Western flanks of these domes it rapidly thickens to 100 and 150 feet. Further away at subsurface points 75 to 125 miles from the Cincinnati Arch some new components lighter in shade and differing in texture—possible correlatives of other members of the Senecan group—come into a maximum thickness

DEVONIAN SHALE IN INDIANA

This outcrop of the New Albany black shale occurs near Scottsburg, Indiana, and is about 100 feet thick. Photo by T. M. Kingsbury.

ranging from 200 to 700 feet. Careful examinations of the cuttings of deep oil and gas drillings in these removed positions reveal the fact that the characteristic jet black color of fresh samples as seen along the outcrop in the type localities is generally absent. The graying modification suggests a lowering of the high carbonaceous content found at the outcrop.

In the depths of the Appalachian geo-syncline where these sediments have been preserved from erosion thicknesses ranging up to 1,000 and more feet are known from deep drilling to be existent though fine stratigraphic distinctions naturally cannot be drawn. These great thicknesses increasing to the north extend into New York and northwestwardly into the northern tip of Michigan. Over this broad territory to the East, North and West exact and detailed correlations have never been made. It is fairily certain, however, that the Chattanooga-New Albany-Ohio shale of the type Southern Indiana and Ohio, Central Kentucky and Tennessee region is the correlative of only a small portion of the long sequence of dark to black fissile shales exhibiting an early Upper Devonian facies at points somewhat removed elsewhere.

Rather lean in fossils, paleontologists have worked on this horizon to great disadvantage. The list is complete with a few small brachiopods, a pteropod, a fish and of course myriads of plant spores. Only occasionally is a plant stem or trunk found as a silicified cast and Dadoxylon is the most frequent in occurrence. The leading brachiopods are Lingulas-brackish water forms. With these is found Leiorhynchus quadricostatus and Schizobolus concentricus type fossils of the Genesee shale of New York. Dinychthys, a Dipnoian, is the fish most usually seen, but specimens are not common. Styliola fissurella is the Pteropod. One of the chief lithological characteristics of the early Upper Devonian black shale of this locality is its tendency to true conchoidal fracture on breaking of fresh and unweathered samples. This is due of course to its highly sporagenous content as has been shown by much detailed microscopic work on thin sections.[7]

[7] Microscopic Examination of Kentucky Oil Shales. Reinhardt Thiessen. Ky. Geol. Survey. Series VI, Vol. XXI, pp. 1-58. 1925.

Economics.

As the direct result of a rather considerable amount of State Geological Survey reconnaissance and laboratory detail work which has been executed during recent years in Indiana, Kentucky, Tennessee, and Pennsylvania it is possible to show the indexing value of the black Upper Devonian shale of these

DEVONIAN SHALT BELT TOPOGRAPHY
Low hills of rounded contour are characteristic of the oil shale region where superimposed Mississippian sediments are gone.

localities as a source for the artificial production of oil and other mineral by-products, in Kentucky an average of 19 samples indexing a specific gravity of 2.18 and a weight of 135.8 lbs. per cu. ft. The oil content of the same number of samples taken from the outcrop surrounding the central northern Blue Grass region of Kentucky gives an average of 16.1 gallons of oil or tar and about 7,158 cubic feet of gas per short ton.[8]

In Southern Indiana the average of a number of outcrop samples was 10.3 gallons of oil per short ton,[9] while in Tennessee such samples as were collected varied from 5 to 20 gallons per ton except in the locality of Franklin, Tennessee, where the amount of oil recovered was nearly double the maximum of

[8] Preliminary Report on the Oil Shales of Kentucky. Willard Rouse Jillson. Kentucky Geological Survey. Series VI, Vol. II, Paper No. 1, pp. 1-37. 1921.

[9] Oil Shales of Indiana. John R. Reeves. Dept. of Geology, Indiana Univ. Mim. Pub., p. 37. 1925.

any other point. It is stated that the average in Tennessee will be about 10 to 14 gallons per ton.[10] Throughout this district the percentage of light oils secured up to 150 degrees Fh. is about 6 to 8% though frequently samples will run as high as 30% up to 150 degrees Fh.

Proceeding away from the type localities of Southern Indiana, Ohio, Kentucky, Tennessee and Northern Alabama in all directions of known outcrop the carbonaceous content of the early Upper Devonian black shale decreases—in some localities rather rapidly, giving some certain indication that the relatively high carbonaceous content of the type locality is definitely associated with the high points along the axis of the Cincinnati anticline. Such shales of early Upper Devonian age as have been sampled at points somewhat distant from the type locality adjacent to central Kentucky and Tennessee are but very slightly productive of oils if at all, the inference being that in the deeper waters of these outlying areas conditions were not well adapted to prolific life either in plant or animal form.

It is estimated that in the type locality of Indiana, Ohio, Kentucky, Tennessee, and Alabama close to the outcrop and within the area of relatively high oil content there is probably a conservative 275,500,000 thousand of tons of Upper Devonian black shale available at the surface. Assuming a mining operating loss slightly in excess of 30 per cent there is at hand in this district 200,000,000 thousands of tons of oil shale suitable for artificial oil production. Assuming further a low average oil content of 13 gallons to the short ton, this amount of oil shale should produce under best retorting methods a conservative 60,000,000 thousands of barrels of 42 gallons each of artificial petroleum—enough oil at the present rate of consumption to last the United States upwards of 100 years. This calculation does not take into account any of the several possible additional by-products which if enumerated would represent enormous values and volumes.[11]

At the present time though many plans are being projected for plants in this locality, particularly in Kentucky which is in

[10] Notes from Unpublished Mss. of J. H. Swartz on Devonian Shale of Tennessee. Tenn. Geol. Survey through L. C. Glenn. 1925.

[11] An Economic Study of the Black Devonian Shales of Kentucky. Charles Stevens Crouse. Ky. Geol. Survey. Series VI, Vol. XXI, pp. 58-97. 1925.

many ways admirably located close to the heart of the population of the United States, intricately traversed by adequate railroad, highway and river lines of transportation, there are no oil shale operations. Furthermore it is not probable that any will be succesfully operated in this district until a somewhat stronger market for natural petroleum develops whereby a

OIL SHALE NEAR JUNCTION CITY, KENTUCKY

price sufficiently large to allow the profitable production of artificial oils is made possible. By way of recapitulation it seems probable that the Black Devonian oil shale of the type locality in Southern Indiana and Ohio, Central Kentucky and Tennessee and Northern Alabama will afford the principal reserve of artificial petroleums for the Eastern United States during the infancy of this probable new industry. At some later time with an advancing market the Sunbury shale in the lower Mississippian and the various oil shales and cannel-shales of the Pennsylvanian throughout the western Appalachian Mountain and Cumberland Plateau region where not adversely affected by high regional metamorphism, will become important artificial oil producing reserves.

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